# MATERIAL FLOWS: JAPAN

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## Highlights

Domestic processed output in Japan grew 20 percent during the period 1975–1996, while the country's population grew by 12.4 percent. Total domestic output in Japan also grew about 20 percent during this period, because of an increase in both DPO and domestic hidden flows. (*See Figure A1.*) The growth in DPO and TDO occurred mainly after the late 1980s. Before then, DPO was almost constant and TDO decreased slightly.

On a per capita basis, there was a downward trend in TDO from the late 1970s to the mid–1980s; DPO per capita also decreased slightly in this period. Growth in DPO per capita and TDO per capita were particularly evident in the late 1980s, when the country experienced the so-called "bubble-economy." (*See Figure A2.*) The absolute level of DPO per capita in Japan is about 4 metric tons without oxygen and 11 metric tons with oxygen. These values are relatively small among the countries studied.

When DPO is calculated excluding oxygen, the data show a smaller increase than when DPO is calculated including oxygen. (*See Figure A3.*) In 1990–1996, the former was almost constant, whereas the latter was increasing. This is because $CO_2$ emissions

FIGURE A1 TOTAL DOMESTIC OUTPUT, JAPAN 1975–1996

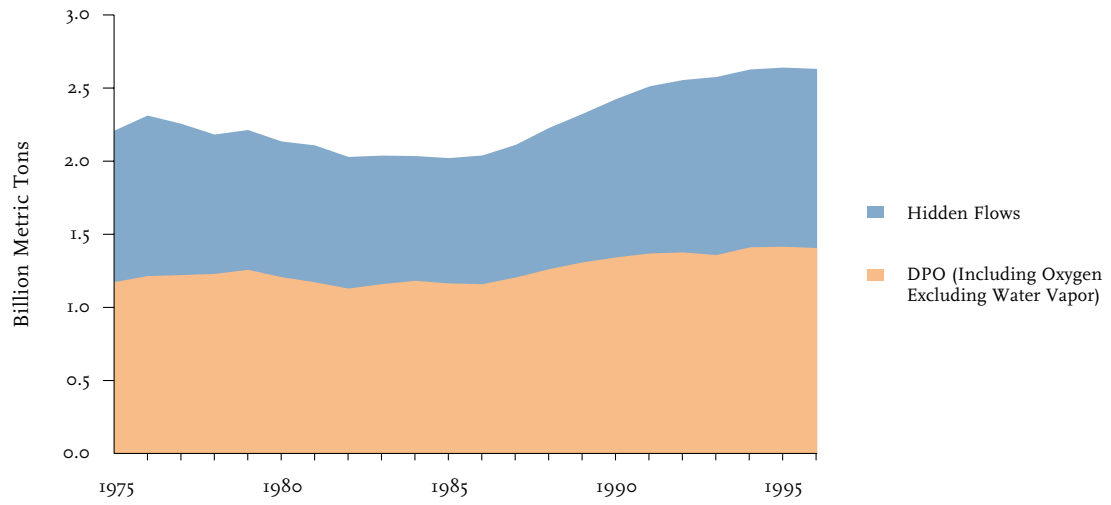


FIGURE A2 TDO, DPO, AND NAS PER CAPITA, JAPAN 1975–1996

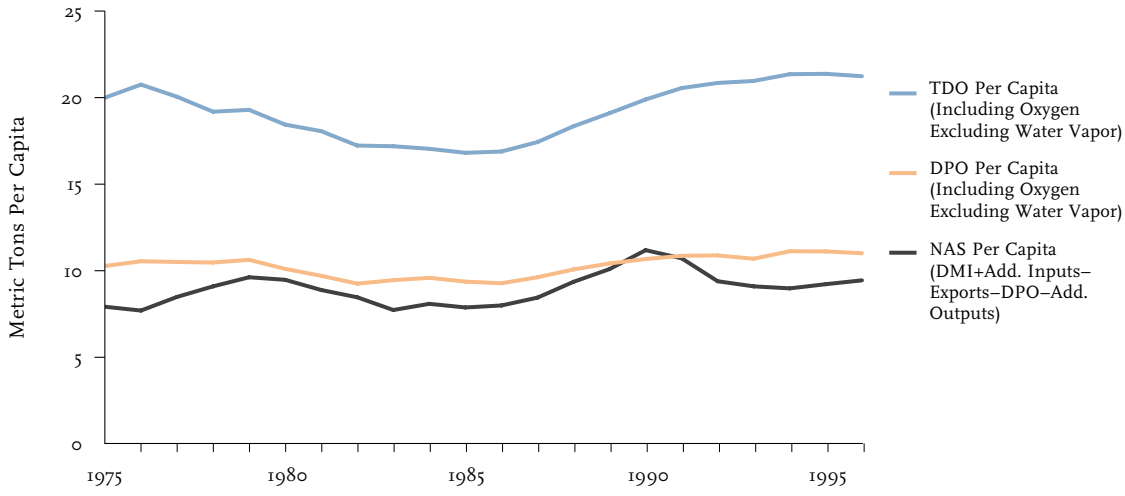



FIGURE A3 TRENDS IN MATERIAL FLOW INDICATORS (INDEX), JAPAN 1975–1996

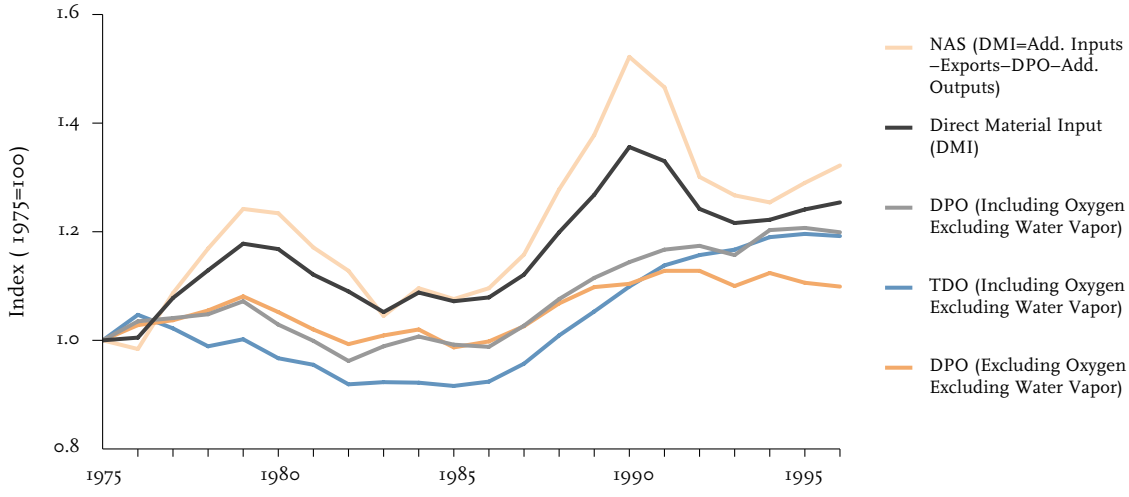


FIGURE A4

## MATERIAL OUTPUT INTENSITY, DENOMINATED BY POPULATION AND GDP (INDEX), JAPAN 1975–1996

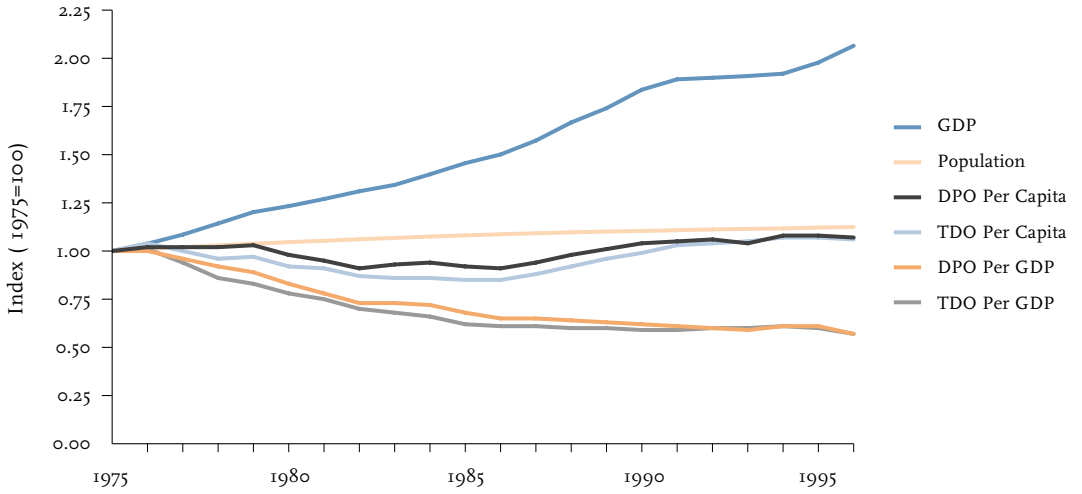
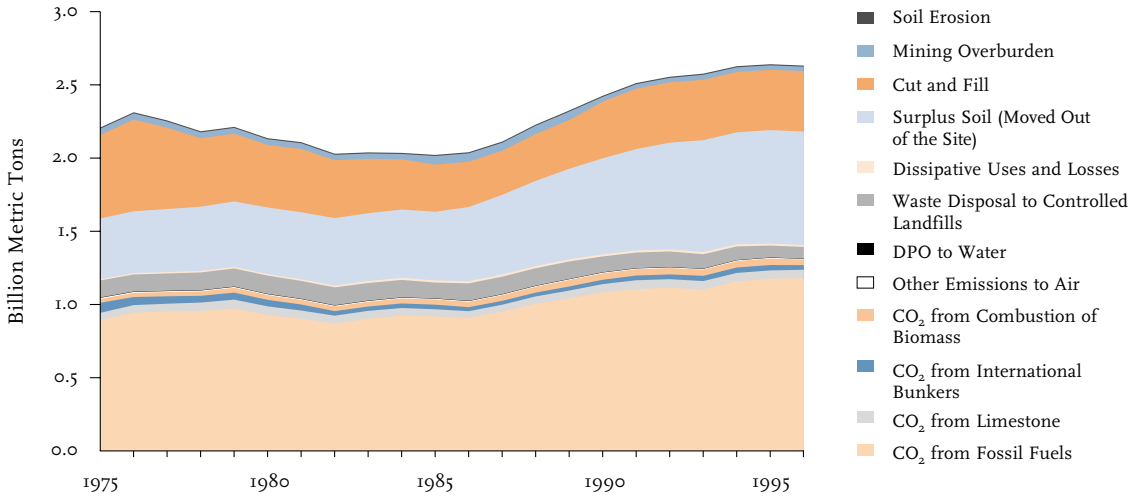



FIGURE A5

## COMPOSITION OF TDO, JAPAN 1975–1996



from fossil fuel combustion, which dominate DPO increased, whereas some other outputs, such as final disposal of solid wastes to land, decreased. In the same period, the direct material input (DMI) of Japan was actually decreasing, mainly because of reduced construction activity following the collapse of the bubble-economy. Net additions to stock (NAS), mainly reflected fluctuations in construction activity. A steep increase in NAS occurred in the late 1980s, the period of the bubble-economy. NAS and DMI show parallel fluctuations. This is because construction materials that are dominant elements of DMI went almost exclusively to stock.

Figure A4 shows that material output intensity, that is, DPO or TDO per constant unit of GDP, and DPO or TDO per capita, declined until 1990 because of larger growth in the monetary economy than in physical throughput (the physical economy). However, since 1990, decoupling between economic growth and material throughput has not improved, because DPO and TDO have continued to increase, while economic growth has slowed down. This recent trend can be explained by structural changes in energy consumption: thanks to relatively cheap oil prices, household energy consumption (including gasoline consumption by private cars) has increased as a proportion of total energy consumption and has contributed to higher $CO_2$ emissions, but this trend has contributed little to GDP growth.

As shown in Figure A5, TDO is dominated by $CO_2$ emissions, particularly from combustion of fossil fuels. $CO_2$ emissions were roughly constant from 1975 to the mid-1980s, then increased from the late 1980s to the 1990s. A steep increase in $CO_2$ emissions, roughly proportional to GDP growth, took place before 1973, that is, before the first oil crisis. These trends are closely related to fluctuations in energy price.

After $CO_2$, waste disposal to controlled landfill sites is the next major component of DPO. This is of greater environmental significance than the nominal weight implies because Japan has a shortage of landfill sites for waste disposal. Reclaiming coastal areas for this purpose has sometimes decreased habitat for wildlife. The weight of waste disposed of in landfill sites is much smaller than that of waste generated. Waste statistics report that 50 million metric tons of municipal solid wastes (MSW) and 400 million metric tons of industrial wastes (both of them measured as wet weight) were generated in 1995. The difference between the amount generated and the amount sent to landfill is the amount recycled or reduced by incineration and drying. Three quarters of MSW is incinerated to reduce waste volumes, but this practice unfortunately generates undesirable byproducts such as air emissions, including dioxins. The amount of landfilled wastes was almost constant until 1990, but is now declining, thanks to waste minimization and recycling measures.

Dissipative use is another important category of output flows. Dissipative flows are dominated by applications of animal manure to fields. Japan classes animal excreta as industrial wastes in waste statistics, but animal excreta used as manure is classed as recycling. Reduction of final disposal of this industrial waste is, thus, offset by dissipative use. Fertilizers and pesticides are intensively used in Japanese agriculture to enhance productivity and compensate for the limited area of available farmland.

Estimates of output flows to water are rough and incomplete, but they are relatively small as far as the quantity of solid materials is concerned. Nevertheless, wastewater flows should be analyzed carefully, because they are an important issue in Japanese environmental policy.

DPO to air accounts for about 90 percent of total DPO. DPO to land is decreasing not only in terms of its relative share of total DPO, but also in absolute amounts.

Soils excavated during construction activities dominate domestic hidden flows. Some portion of excavated soil is moved out of the construction site, then dumped into landfills or used for other purposes, while another portion remains within the same site (cut and fill). Only "surplus soil," which means the soil excavated then moved out of the construction site to landfill or other sites for application, is quantified by official surveys. The total quantity of soil excavation by construction activities is much greater, because excavation work is usually designed to balance cut and fill, to use excavated soil on site, and minimize the generation of surplus soil. The total size of excavations may be a better indicator of landscape alteration. However, as an indicator of output flows, we may differentiate the surplus soil from the excavated soil for on-site application. The former has greater environmental significance. For this reason, these two types of soil are separately shown in the data sheet and Figure A5.

Hidden flows associated with mining activities are trivial in quantity, because of the limited resources of fossil fuels and metal ores in Japan. Consequently, the contribution of domestic hidden flows to TDO is relatively small, compared with more resource-rich countries. It should be borne in mind that the small size of domestic hidden flows is counterbalanced by imported hidden flows associated with imported metals and energy carriers; this represents the transfer of Japan's environmental burden to its trade partners, which the study by Adriaanse et al., 1997 emphasized.

When disaggregated by economic activities, different sectors contribute to different types of output flows. For DPO, the energy supply sector and the manufacturing sector are large contributors because of their high levels of $CO_2$ emissions. In the case of TDO, the construction sector surpasses these two sectors, because of large amounts of excavated soil. (*See Figure A6, Figure A7.*)

Net additions of materials to stock (NAS) in the Japanese technosphere have fluctuated in accordance with patterns of governmental and private investment. NAS increased significantly in the late 1980s, then stabilized at a lower level in 1990. Because Japan has a shorter history of industrialization than other Western countries, construction work is still active and significantly contributes to the country's overall picture of material flows. As much as 60 percent of direct material input (DMI) is added to the stock. This figure also has a close relation with inputs of construction materials as well as with soil excavation. Increasing quantities of stock imply that demolition wastes will also increase in the future. Currently, the government is attempting to encourage recycling of demolition wastes.

FIGURE A6 DPO BY ECONOMIC SECTOR, JAPAN 1975–1996

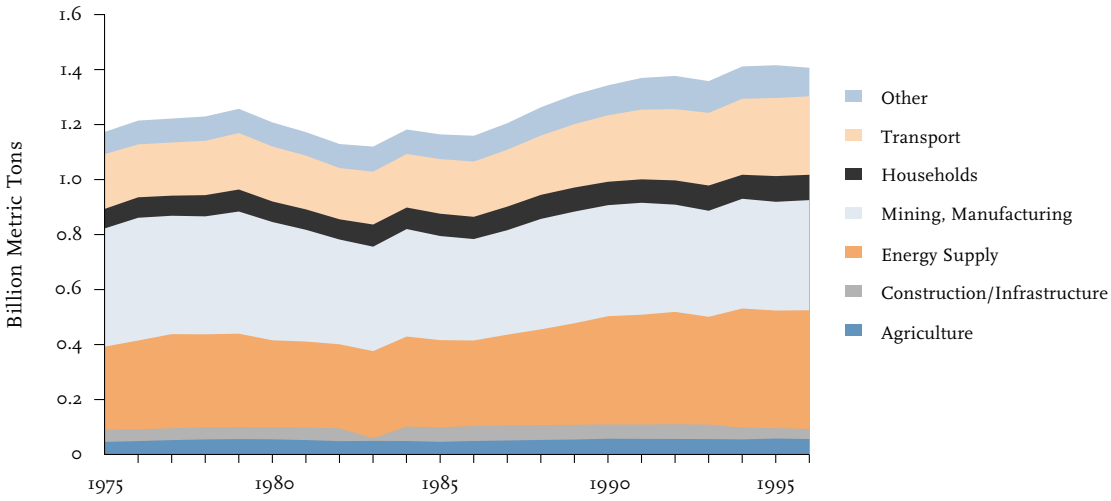
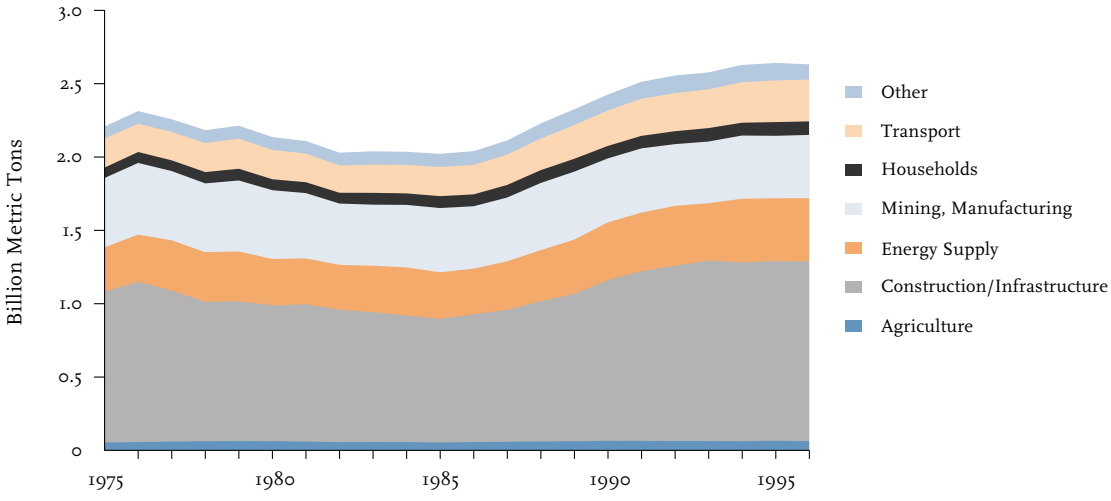



FIGURE A7 TDO BY ECONOMIC SECTOR, JAPAN 1975–1996



## Material Output Flows: Japan, 1975-1996

*All units 1,000 metric tons unless otherwise stated*

| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Summary Data** | | | | | | | | | | | |
| Population *(1,000)* | 111,940 | 113,089 | 114,154 | 115,190 | 116,155 | 117,060 | 117,902 | 118,728 | 119,536 | 120,305 | 121,049 |
| GDP *(constant 1996 billion Yen)* | 244,291 | 253,485 | 264,962 | 279,308 | 293,689 | 301,324 | 310,333 | 319,943 | 328,037 | 341,485 | 355,578 |
| Direct Material Inputs *(DMI)* | 1,606,827 | 1,615,133 | 1,731,611 | 1,814,777 | 1,893,402 | 1,876,801 | 1,801,146 | 1,750,743 | 1,690,602 | 1,748,064 | 1,721,813 |
| Domestic Extraction | 1,057,244 | 1,042,953 | 1,141,952 | 1,254,627 | 1,282,480 | 1,272,136 | 1,235,600 | 1,192,844 | 1,145,634 | 1,150,915 | 1,128,236 |
| Imports | 549,583 | 572,179 | 589,659 | 560,149 | 610,921 | 604,665 | 565,546 | 557,898 | 544,968 | 597,149 | 593,578 |
| Exports | 66,404 | 72,895 | 84,601 | 80,589 | 75,128 | 81,303 | 78,921 | 77,634 | 85,457 | 85,851 | 90,265 |
| **Summary Indicators** *(as presented in main report)* | | | | | | | | | | | |
| DPO *(including Oxygen)* | 1,173,248 | 1,214,487 | 1,221,840 | 1,229,516 | 1,257,203 | 1,207,858 | 1,172,354 | 1,129,212 | 1,159,912 | 1,182,004 | 1,164,346 |
| DPO *(excluding Oxygen)* | 451,507 | 464,037 | 468,201 | 476,459 | 488,174 | 475,024 | 460,754 | 448,424 | 455,687 | 460,398 | 445,822 |
| Domestic hidden flows | 1,035,239 | 1,098,663 | 1,035,788 | 953,969 | 956,304 | 928,239 | 936,756 | 900,864 | 879,325 | 853,752 | 857,527 |
| TDO *(including Oxygen)* | 2,208,487 | 2,313,150 | 2,257,627 | 2,183,484 | 2,213,507 | 2,136,097 | 2,109,109 | 2,030,076 | 2,039,237 | 2,035,757 | 2,021,874 |
| TDO *(excluding Oxygen)* | 1,486,746 | 1,562,701 | 1,503,988 | 1,430,428 | 1,444,479 | 1,403,263 | 1,397,510 | 1,349,288 | 1,335,012 | 1,314,150 | 1,303,350 |
| Net Additions to Stock | 922,408 | 908,016 | 1,002,246 | 1,078,176 | 1,145,300 | 1,138,233 | 1,079,684 | 1,040,332 | 963,664 | 1,010,948 | 992,607 |
| *(DMI + Add'l Inputs - Exports - DPO - Add'l outputs)* | | | | | | | | | | | |
| **Summary Indicators** *(metric tons per capita)* | | | | | | | | | | | |
| DPO *(including Oxygen)* | 10.48 | 10.74 | 10.70 | 10.67 | 10.82 | 10.32 | 9.94 | 9.51 | 9.70 | 9.83 | 9.62 |
| DPO *(excluding Oxygen)* | 4.03 | 4.10 | 4.10 | 4.14 | 4.20 | 4.06 | 3.91 | 3.78 | 3.81 | 3.83 | 3.68 |
| Domestic hidden flows | 9.25 | 9.72 | 9.07 | 8.28 | 8.23 | 7.93 | 7.95 | 7.59 | 7.36 | 7.10 | 7.08 |
| TDO *(including Oxygen)* | 19.73 | 20.45 | 19.78 | 18.96 | 19.06 | 18.25 | 17.89 | 17.10 | 17.06 | 16.92 | 16.70 |
| TDO *(excluding Oxygen)* | 13.28 | 13.82 | 13.18 | 12.42 | 12.44 | 11.99 | 11.85 | 11.36 | 11.17 | 10.92 | 10.77 |
| Net Additions to Stock | 8.24 | 8.03 | 8.78 | 9.36 | 9.86 | 9.72 | 9.16 | 8.76 | 8.06 | 8.40 | 8.20 |
| *(DMI + Add'l Inputs - Exports - DPO - Add'l outputs)* | | | | | | | | | | | |
| **Summary Indicators including additional outputs** *(not presented in main report)* | | | | | | | | | | | |
| DPO | 1,226,827 | 1,268,763 | 1,277,492 | 1,286,560 | 1,315,464 | 1,266,903 | 1,232,133 | 1,189,611 | 1,221,164 | 1,244,143 | 1,227,073 |
| *(including carbon dioxide from respiration, excluding water vapor from all combustion & respiration)* | | | | | | | | | | | |
| DPO | 1,643,877 | 1,702,293 | 1,722,093 | 1,738,854 | 1,778,475 | 1,709,445 | 1,665,566 | 1,613,775 | 1,657,524 | 1,694,175 | 1,677,665 |
| *(including carbon dioxide from respiration, including water vapor from all combustion & respiration)* | | | | | | | | | | | |
| TDO | 2,262,067 | 2,367,427 | 2,313,279 | 2,240,529 | 2,271,768 | 2,195,142 | 2,168,888 | 2,090,475 | 2,100,488 | 2,097,896 | 2,084,600 |
| *(including carbon dioxide from respiration, excluding water vapor from all combustion & respiration)* | | | | | | | | | | | |
| TDO | 2,679,116 | 2,800,957 | 2,757,880 | 2,692,822 | 2,734,780 | 2,637,684 | 2,602,322 | 2,514,639 | 2,536,848 | 2,547,927 | 2,535,192 |
| *(including carbon dioxide from respiration, including water vapor from all combustion & respiration)* | | | | | | | | | | | |
| **Gateway Indicators** | | | | | | | | | | | |
| **DPO to Air** | 1,045,306 | 1,086,022 | 1,091,417 | 1,095,450 | 1,120,275 | 1,070,118 | 1,036,819 | 992,547 | 1,024,370 | 1,046,838 | 1,039,495 |
| *(including oxygen from all combustion, excluding oxygen from respiration, excluding all water vapor)* | | | | | | | | | | | |
| Total $CO_2$ | 1,038,199 | 1,079,353 | 1,085,186 | 1,089,339 | 1,114,285 | 1,064,248 | 1,031,147 | 987,073 | 1,019,093 | 1,041,754 | 1,034,603 |
| *(from non-biological activities)* | | | | | | | | | | | |
| $CO_2$ from fossil fuels | 961,878 | 999,951 | 1,003,827 | 1,002,123 | 1,021,092 | 972,034 | 944,338 | 900,944 | 932,591 | 954,983 | 949,651 |
| *(incl. Bunkers)* | | | | | | | | | | | |
| $CO_2$ from limestone | 49,770 | 51,153 | 52,304 | 57,178 | 60,084 | 59,735 | 55,721 | 53,903 | 53,588 | 52,243 | 49,224 |
| *(cement making)* | | | | | | | | | | | |
| $CO_2$ from combustion of biomass | 26,551 | 28,249 | 29,055 | 30,039 | 33,109 | 32,480 | 31,088 | 32,226 | 32,914 | 34,528 | 35,728 |
| $SO_x$ | 2,586 | 2,134 | 1,682 | 1,547 | 1,412 | 1,277 | 1,201 | 1,125 | 1,049 | 978 | 906 |
| $NO_x$ | 2,286 | 2,300 | 2,315 | 2,329 | 2,344 | 2,358 | 2,298 | 2,238 | 2,178 | 2,118 | 2,058 |
| VOC | 2,234 | 2,234 | 2,234 | 2,234 | 2,234 | 2,234 | 2,173 | 2,111 | 2,050 | 1,989 | 1,927 |
| Bunker Fuel Emissions | | | | | | | | | | | |
| $CO_2$ from international bunkers | 68,688 | 55,235 | 50,714 | 45,921 | 47,717 | 44,397 | 41,199 | 31,191 | 29,589 | 31,095 | 31,315 |
| **DPO to Land** | 125,588 | 126,142 | 128,133 | 131,812 | 134,710 | 135,560 | 133,393 | 134,563 | 133,479 | 133,143 | 122,850 |
| Municipal solid wastes | | | | | | | | | | | |
| to controlled landfill | 21,017 | 19,093 | 18,709 | 19,900 | 20,357 | 19,718 | 17,257 | 18,174 | 16,769 | 16,192 | 16,031 |
| Industrial wastes | | | | | | | | | | | |
| to controlled landfill | 95,583 | 97,560 | 99,538 | 101,515 | 103,492 | 105,469 | 104,848 | 104,226 | 103,604 | 102,983 | 92,269 |
| Dissipative flows to land | 8,987 | 9,489 | 9,887 | 10,397 | 10,860 | 10,373 | 11,289 | 12,163 | 13,105 | 13,969 | 14,550 |
| Animal manure spread on fields | 6,551 | 6,662 | 7,037 | 7,439 | 7,770 | 7,929 | 8,735 | 9,464 | 10,269 | 11,097 | 11,801 |
| *(dry weight)* | | | | | | | | | | | |
| Mineral fertilizers | 2,343 | 2,733 | 2,756 | 2,864 | 2,996 | 2,354 | 2,465 | 2,612 | 2,75 | 2,788 | 2,666 |
| Pesticides | 94 | 94 | 94 | 94 | 94 | 90 | 88 | 87 | 86 | 84 | 83 |

## Material Output Flows: Japan, 1975-1996

*All units 1,000 metric tons unless otherwise stated*

| 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | **Summary Data** |
| 121,660 | 122,239 | 122,745 | 123,205 | 123,611 | 124,043 | 124,452 | 124,764 | 125,034 | 125,570 | 125,864 | Population *(1,000)* |
| 366,737 | 384,181 | 407,133 | 425,238 | 448,834 | 462,070 | 463,823 | 466,038 | 469,056 | 483,150 | 504,391 | GDP *(constant 1996 billion Yen)* |
| 1,733,928 | 1,800,867 | 1,927,167 | 2,037,678 | 2,178,946 | 2,136,390 | 1,994,923 | 1,953,262 | 1,964,128 | 1,993,803 | 2,014,507 | Direct Material Inputs *(DMI)* |
| 1,154,166 | 1,204,430 | 1,273,743 | 1,358,063 | 1,478,469 | 1,424,593 | 1,330,753 | 1,285,835 | 1,272,303 | 1,247,113 | 1,259,685 | Domestic Extraction |
| 579,762 | 596,438 | 653,424 | 679,615 | 700,477 | 711,797 | 664,170 | 667,427 | 691,825 | 746,691 | 754,822 | Imports |
| 78,125 | 71,456 | 66,250 | 66,562 | 70,044 | 69,417 | 78,008 | 85,300 | 90,071 | 94,708 | 93,903 | Exports |
| | | | | | | | | | | | **Summary Indicators** *(as presented in main report)* |
| 1,159,296 | 1,205,142 | 1,262,996 | 1,308,752 | 1,342,746 | 1,369,576 | 1,376,895 | 1,358,031 | 1,411,440 | 1,415,875 | 1,406,548 | DPO *(including Oxygen)* |
| 450,608 | 463,371 | 482,035 | 495,894 | 498,512 | 509,322 | 509,271 | 496,541 | 507,560 | 499,566 | 496,254 | DPO *(excluding Oxygen)* |
| 880,985 | 907,883 | 966,159 | 1,016,797 | 1,083,518 | 1,143,305 | 1,179,083 | 1,218,958 | 1,216,468 | 1,225,538 | 1,225,538 | Domestic hidden flows |
| 2,040,282 | 2,113,025 | 2,229,155 | 2,325,549 | 2,426,264 | 2,512,881 | 2,555,979 | 2,576,989 | 2,627,908 | 2,641,413 | 2,632,086 | TDO *(including Oxygen)* |
| 1,331,593 | 1,371,254 | 1,448,194 | 1,512,691 | 1,582,030 | 1,652,627 | 1,688,355 | 1,715,500 | 1,724,028 | 1,725,105 | 1,721,792 | TDO *(excluding Oxygen)* |
| 1,010,751 | 1,068,144 | 1,178,999 | 1,270,782 | 1,403,571 | 1,351,889 | 1,200,056 | 1,168,324 | 1,156,832 | 1,190,357 | 1,219,305 | Net Additions to Stock |
| | | | | | | | | | | | *(DMI + Add'l Inputs - Exports - DPO - Add'l outputs)* |
| | | | | | | | | | | | **Summary Indicators** *(metric tons per capita)* |
| 9.53 | 9.86 | 10.29 | 10.62 | 10.86 | 11.04 | 11.06 | 10.88 | 11.29 | 11.28 | 11.18 | DPO *(including Oxygen)* |
| 3.70 | 3.79 | 3.93 | 4.02 | 4.03 | 4.11 | 4.09 | 3.98 | 4.06 | 3.98 | 3.94 | DPO *(excluding Oxygen)* |
| 7.24 | 7.43 | 7.87 | 8.25 | 8.77 | 9.22 | 9.47 | 9.77 | 9.73 | 9.76 | 9.74 | Domestic hidden flows |
| 16.77 | 17.29 | 18.16 | 18.88 | 19.63 | 20.26 | 20.54 | 20.65 | 21.02 | 21.04 | 20.91 | TDO *(including Oxygen)* |
| 10.95 | 11.22 | 11.80 | 12.28 | 12.80 | 13.32 | 13.57 | 13.75 | 13.79 | 13.74 | 13.68 | TDO *(excluding Oxygen)* |
| 8.31 | 8.74 | 9.61 | 10.31 | 11.35 | 10.90 | 9.64 | 9.36 | 9.25 | 9.48 | 9.69 | Net Additions to Stock |
| | | | | | | | | | | | *(DMI + Add'l Inputs - Exports - DPO - Add'l outputs)* |
| | | | | | | | | | | | **Summary Indicators including additional outputs** *(not presented in main report)* |
| 1,222,694 | 1,268,843 | 1,326,952 | 1,372,888 | 1,407,058 | 1,434,020 | 1,441,744 | 1,423,016 | 1,476,101 | 1,480,059 | 1,470,366 | DPO |
| | | | | | | | | | | | *(including carbon dioxide from respiration, excluding water vapor from all combustion & respiration)* |
| 1,673,752 | 1,735,939 | 1,811,254 | 1,874,758 | 1,926,544 | 1,961,361 | 1,975,023 | 1,948,739 | 2,025,759 | 2,034,452 | 2,020,362 | DPO |
| | | | | | | | | | | | *(including carbon dioxide from respiration, including water vapor from all combustion & respiration)* |
| 2,103,679 | 2,176,726 | 2,293,111 | 2,389,685 | 2,490,577 | 2,577,325 | 2,620,827 | 2,641,974 | 2,692,569 | 2,705,597 | 2,695,904 | TDO |
| | | | | | | | | | | | *(including carbon dioxide from respiration, excluding water vapor from all combustion & respiration)* |
| 2,554,737 | 2,643,822 | 2,777,413 | 2,891,555 | 3,010,063 | 3,104,666 | 3,154,107 | 3,167,697 | 3,242,227 | 3,259,990 | 3,245,901 | TDO |
| | | | | | | | | | | | *(including carbon dioxide from respiration, including water vapor from all combustion & respiration)* |
| | | | | | | | | | | | **Gateway Indicators** |
| 1,023,626 | 1,068,896 | 1,126,752 | 1,172,620 | 1,218,338 | 1,246,213 | 1,253,655 | 1,243,336 | 1,301,992 | 1,319,113 | 1,311,982 | **DPO to Air** |
| | | | | | | | | | | | *(including oxygen from all combustion, excluding oxygen from respiration, excluding all water vapor)* |
| 11,018,768 | ,063,985 | 1,121,789 | 1,167,605 | 1,213,194 | 1,241,072 | 1,248,673 | 1,238,536 | 1,297,035 | 1,314,176 | 1,307,247 | Total $CO_2$ |
| | | | | | | | | | | | *(from non-biological activities)* |
| 935,010 | 978,460 | 1,030,789 | 1,070,648 | 1,114,181 | 1,136,910 | 1,147,209 | 1,139,252 | 1,196,053 | 1,212,703 | 1,210,793 | $CO_2$ from fossil fuels |
| | | | | | | | | | | | *(incl. Bunkers)* |
| 46,893 | 46,662 | 50,617 | 52,614 | 55,152 | 61,065 | 58,431 | 56,617 | 56,923 | 56,960 | 58,087 | $CO_2$ from limestone |
| | | | | | | | | | | | *(cement making)* |
| 36,865 | 38,863 | 40,383 | 44,342 | 43,860 | 43,096 | 43,034 | 42,667 | 44,060 | 44,513 | 38,368 | $CO_2$ from combustion of biomass |
| 835 | 849 | 862 | 876 | 966 | 976 | 895 | 814 | 847 | 827 | 805 | $SO_x$ |
| 2,089 | 2,120 | 2,150 | 2,181 | 2,212 | 2,271 | 2,222 | 2,163 | 2,237 | 2,237 | 2,029 | $NO_x$ |
| 1,935 | 1,943 | 1,951 | 1,958 | 1,966 | 1,894 | 1,865 | 1,823 | 1,873 | 1,873 | 1,901 | VOC |
| | | | | | | | | | | | Bunker Fuel Emissions |
| 27,432 | 26,496 | 25,955 | 27,973 | 29,986 | 32,189 | 32,668 | 35,839 | 37,053 | 36,817 | 31,587 | $CO_2$ from international bunkers |
| 133,691 | 134,290 | 134,313 | 134,226 | 122,531 | 121,514 | 121,419 | 112,903 | 107,684 | 95,021 | 92,854 | **DPO to Land** |
| | | | | | | | | | | | Municipal solid wastes |
| 16,023 | 16,490 | 16,900 | 17,490 | 16,809 | 16,379 | 15,296 | 14,959 | 14,142 | 13,602 | 13,093 | to controlled landfill |
| | | | | | | | | | | | Industrial wastes |
| 102,872 | 102,979 | 102,680 | 101,975 | 91,145 | 90,601 | 91,503 | 83,324 | 79,207 | 68,035 | 66,554 | to controlled landfill |
| 14,795 | 14,822 | 14,733 | 14,760 | 14,577 | 14,534 | 14,619 | 14,619 | 14,335 | 13,384 | 13,207 | Dissipative flows to land |
| 11,994 | 12,049 | 12,088 | 12,083 | 12,043 | 12,091 | 12,159 | 12,139 | 11,899 | 11,115 | 11,018 | Animal manure spread on fields |
| | | | | | | | | | | | *(dry weight)* |
| 2,722 | 2,697 | 2,575 | 2,609 | 2,466 | 2,377 | 2,395 | 2,415 | 2,371 | 2,205 | 2,124 | Mineral fertilizers |
| 79 | 76 | 70 | 69 | 68 | 66 | 65 | 65 | 65 | 65 | 65 | Pesticides |

## Material Output Flows: Japan, 1975-1996

*All units 1,000 metric tons unless otherwise stated*

| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **DPO to Water** | 2,355 | 2,323 | 2,289 | 2,254 | 2,218 | 2,181 | 2,142 | 2,103 | 2,063 | 2,023 | 2,002 |
| Organic load *(as COD)* | 1,339 | 1,316 | 1,293 | 1,269 | 1,244 | 1,218 | 1,191 | 1,165 | 1,138 | 1,111 | 1,093 |
| T-N | 914 | 908 | 902 | 894 | 887 | 878 | 870 | 861 | 852 | 842 | 841 |
| T-P | 102 | 98 | 95 | 91 | 88 | 84 | 81 | 77 | 73 | 70 | 68 |
| **Additional Inputs** | 1,025,861 | 1,068,072 | 1,077,329 | 1,082,842 | 1,105,501 | 1,052,180 | 1,023,026 | 980,998 | 1,016,042 | 1,042,909 | 1,038,724 |
| *(not presented in main report)* | | | | | | | | | | | |
| Oxygen in combustion | 986,894 | 1,028,598 | 1,036,855 | 1,041,355 | 1,063,129 | 1,009,239 | 979,550 | 937,071 | 971,496 | 997,717 | 993,105 |
| Oxygen in respiration | 38,967 | 39,474 | 40,474 | 41,487 | 42,372 | 42,942 | 43,475 | 43,927 | 44,547 | 45,192 | 45,619 |
| **Additional Outputs** | 470,629 | 487,807 | 500,253 | 509,338 | 521,273 | 501,587 | 493,213 | 484,562 | 497,611 | 512,170 | 513,318 |
| *(not presented in main report)* | | | | | | | | | | | |
| Water vapor | | | | | | | | | | | |
| from fossil combustion | 321,384 | 336,431 | 341,632 | 346,737 | 354,318 | 335,419 | 325,369 | 311,102 | 324,325 | 335,666 | 334,263 |
| Water vapor | | | | | | | | | | | |
| from biomass combustion | 9,051 | 9,630 | 9,905 | 10,241 | 11,287 | 11,073 | 10,598 | 10,986 | 11,221 | 11,771 | 12,180 |
| Water vapor from respiration | 21,919 | 22,204 | 22,767 | 23,336 | 23,834 | 24,155 | 24,455 | 24,709 | 25,057 | 25,420 | 25,661 |
| Water included in DMI | | | | | | | | | | | |
| as water contents of food & feed | 64,695 | 65,265 | 70,297 | 71,980 | 73,571 | 71,897 | 73,012 | 77,366 | 75,757 | 77,174 | 78,489 |
| $CO_2$ from respiration | 53,580 | 54,276 | 55,652 | 57,044 | 58,262 | 59,045 | 59,779 | 60,399 | 61,252 | 62,139 | 62,726 |
| **Domestic Hidden Flows** | 1,035,239 | 1,098,663 | 1,035,788 | 953,969 | 956,304 | 928,239 | 936,756 | 900,864 | 879,325 | 853,752 | 857,527 |
| Excavated soil | | | | | | | | | | | |
| by construction activities | 984,388 | 1,048,942 | 986,430 | 906,699 | 909,487 | 881,809 | 890,430 | 856,652 | 835,279 | 810,620 | 790,518 |
| Surplus soil | 414,358 | 422,507 | 430,655 | 438,803 | 446,951 | 455,100 | 458,008 | 460,917 | 463,826 | 466,735 | 469,644 |
| *(moved out of the site)* | | | | | | | | | | | |
| Cut & Fill | 570,029 | 626,435 | 555,776 | 467,896 | 462,536 | 426,710 | 432,422 | 395,735 | 371,453 | 343,886 | 320,875 |
| Soil erosion | 7,682 | 7,575 | 7,438 | 7,367 | 7,355 | 7,384 | 7,396 | 7,420 | 7,444 | 7,450 | 7,492 |
| Mining overburden | 43,169 | 42,146 | 41,919 | 39,903 | 39,463 | 39,045 | 38,929 | 36,792 | 36,601 | 35,682 | 59,517 |

## Material Output Flows: Japan, 1975-1996

*All units 1,000 metric tons unless otherwise stated*

| 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,979 | 1,955 | 1,931 | 1,905 | 1,877 | 1,849 | 1,821 | 1,792 | 1,763 | 1,741 | 1,712 | **DPO to Water** |
| 1,073 | 1,054 | 1,034 | 1,014 | 988 | 962 | 936 | 909 | 883 | 859 | 833 | Organic load *(as COD)* |
| 839 | 836 | 833 | 829 | 828 | 827 | 826 | 824 | 822 | 824 | 822 | T-N |
| 67 | 65 | 64 | 62 | 61 | 61 | 60 | 59 | 58 | 57 | 57 | T-P |
| 1,028,700 | 1,074,672 | 1,129,336 | 1,174,424 | 1,221,213 | 1,246,276 | 1,258,165 | 1,249,101 | 1,308,534 | 1,325,713 | 1,319,063 | **Additional Inputs** |
| | | | | | | | | | | | *(not presented in main report)* |
| 982,592 | 1,028,344 | 1,082,823 | 1,127,780 | 1,174,441 | 1,199,408 | 1,211,002 | 1,201,839 | 1,261,507 | 1,279,034 | 1,272,650 | Oxygen in combustion |
| 46,108 | 46,328 | 46,514 | 46,645 | 46,773 | 46,868 | 47,162 | 47,262 | 47,027 | 46,680 | 46,413 | Oxygen in respiration |
| 514,456 | 530,798 | 548,258 | 566,007 | 583,799 | 591,785 | 598,128 | 590,708 | 614,319 | 618,577 | 613,814 | **Additional Outputs** |
| | | | | | | | | | | | *(not presented in main report)* |
| 332,408 | 347,688 | 366,000 | 381,825 | 398,932 | 410,016 | 415,084 | 412,224 | 433,310 | 439,705 | 439,754 | Water vapor from fossil combustion |
| 12,568 | 13,249 | 13,767 | 15,117 | 14,952 | 14,692 | 14,671 | 14,546 | 15,020 | 15,175 | 13,080 | Water vapor from biomass combustion |
| 25,936 | 26,060 | 26,164 | 26,238 | 26,310 | 26,364 | 26,529 | 26,585 | 26,452 | 26,257 | 26,107 | Water vapor from respiration |
| 80,147 | 80,099 | 78,371 | 78,691 | 79,292 | 76,269 | 76,997 | 72,368 | 74,874 | 73,255 | 71,055 | Water included in DMI as water contents of food & feed |
| 63,398 | 63,702 | 63,956 | 64,136 | 64,313 | 64,444 | 64,848 | 64,985 | 64,662 | 64,184 | 63,818 | $CO_2$ from respiration |
| 880,985 | 907,883 | 966,159 | 1,016,797 | 1,083,518 | 1,143,305 | 1,179,083 | 1,218,958 | 1,216,468 | 1,225,538 | 1,225,538 | **Domestic Hidden Flows** |
| | | | | | | | | | | | Excavated soil |
| 816,720 | 845,300 | 901,947 | 951,758 | 1,043,621 | 1,104,647 | 1,140,813 | 1,176,980 | 1,176,980 | 1,187,480 | 1,187,480 | by construction activities |
| 506,965 | 544,286 | 581,607 | 618,929 | 656,250 | 692,417 | 728,583 | 764,750 | 764,750 | 775,250 | 775,250 | Surplus soil |
| | | | | | | | | | | | *(moved out of the site)* |
| 309,755 | 301,014 | 320,339 | 332,829 | 387,371 | 412,230 | 412,230 | 412,230 | 412,230 | 412,230 | 412,230 | Cut & Fill |
| 7,527 | 7,587 | 7,629 | 7,641 | 7,599 | 7,545 | 7,474 | 7,408 | 7,355 | 7,355 | 7,355 | Soil erosion |
| 56,738 | 54,995 | 56,583 | 57,398 | 32,298 | 31,113 | 30,796 | 34,570 | 32,134 | 30,704 | 30,704 | Mining overburden |

## Data Sources and Methodology: Technical Notes

Japanese data were drawn from official statistical sources of various ministries and agencies as well as from academic literature and personal communications with experts. Official sources include Environment Agency (EA), Ministry of Agriculture, Forestry and Fisheries (MAFF), Ministry of International Trade and Industry (MITI), Ministry of Health and Welfare (MHW), and Ministry of Construction (MOC). Most of the Japanese data are presented on a fiscal year basis rather than calendar year.

### *DMO to Air*

#### *Carbon Dioxide and Water Vapor Emissions, and Oxygen Input*

Inventories of $CO_2$ emissions have been officially reported based on the United Nations Framework Convention for Climate Change (UNFCCC) using Intergovernmental Panel on Climate Change (IPCC) guidelines for greenhouse gas (GHG) emissions and Japanese country-specific methodologies. However, this official inventory is not enough to provide a complete balance of $CO_2$, oxygen, and water vapor. The official inventories do not cover $CO_2$ that is not contributing to the greenhouse effect, namely, from digestion of food or feed by animals (including human beings). Therefore, emissions of $CO_2$, water, and extra inputs of oxygen for oxidation of carbon and hydrogen were newly estimated for this study. Results were compared with official inventories to prove that both data sets coincide with each other within acceptable margins of error (less than a few percent). The outline of our estimation method is as follows: for fossil fuels, carbon and hydrogen, contents were assumed by type of fuels; for example, 0.85, 0.12 for crude oil; 0.865, 0.125 for petroleum products; 0.76, 0.055 for coking coal; 0.645, 0.05 for fuel coal; 0.75, 0.25 for natural gas. Using such fractions, $CO_2$ and water produced and oxygen taken in by combustion of fuels were estimated stochiometrically.

Emissions from incinerating fuels used for international transport (heavy oil for navigation, and jet fuel for aviation) were included as a part of the transport sector's activities. $CO_2$ and water from biofuels (as in the case of the paper and pulp industry) as well as those from waste incineration, were estimated by applying the same procedure and listed in the dataset separately. $CO_2$ originating from limestone for cement and other industrial activities was estimated by applying the same methodology as the official inventory, namely as a product of the carbon fraction of limestone and apparent consumption of limestone for various activities.

Human respiration was calculated on the basis of an average $CO_2$ production of 0.3 metric tons per capita per year. The respiration of livestock was calculated on the basis of the number of cattle, pigs, poultry, and other animals (MAFF) and exhalation factors for each animal (Wuppertal Institute, except for cattle data). Factors applied in tons of $CO_2$ per year were as follows: cattle 1.6, pigs 0.327, poultry 0.027, sheep/goats 0.254, and horses 1.33. Material balances among feed intake, exhalation, and excreta validate these estimates. For example, as much as one third of feed intake by cattle is not digested but voided as excreta. To cross check, the amount of excreta estimated from feed inputs was compared with the amount of animal manure in industrial wastes.

*Sulfur Dioxide, Oxides of Nitrogen, and Non-Methane Volatile Organic Compounds*

The data for $SO_2$, $NO_x$, and NMVOC to air since 1990 were drawn from official GHG inventories. Before 1990, emissions of $SO_2$ and $NO_x$ were reported only in international literature (OECD) or documents covering only short time intervals. Emissions of NMVOC before 1990 were not published; only unofficial estimates are available. Although certain inconsistencies exist among data before and after 1990, no correction was applied, time-series data were simply quoted from multiple data sources. Moreover, although a considerable percentage of NMVOC originates from dissipative use of products (e.g., solvents and paints), they are not categorized in the Japanese dataset as dissipative uses, but as outputs to air.

Another problem is that these inventories cover only emissions from sources on land and from navigation along Japanese coastal areas, even though Japan's heavy dependence on resource imports is accompanied by emissions from vessels far from Japanese territory. Given that the emission factors of $SO_x$ and $NO_2$ per unit fuel consumption for ocean-going vessels are high (IPCC), the figures in this report are certainly underestimates. $SO_2$ and $NO_x$ originating from international bunker oil will have to be added in future analyses, which will result in significant changes to the data presented here.

## *DMO to Land*

*Waste Disposal to Controlled Landfills*

Data on wastes generated, treated, recycled or disposed at landfill sites were available for municipal solid wastes and industrial wastes respectively, from MHW. Industrial wastes are subdivided into 19 types: embers; sludge; waste oil; waste acid; waste alkali; waste plastics; waste paper; wood debris; waste fiber; animal and plant residues; waste rubber; metal scrap; glass and ceramic debris; slag; construction scrap wood; livestock excreta; animal corpses; soot and dust; and others. The total amounts of each type of wastes from all industries and the total amounts of all wastes from each type of industries are available in time series. However, cross tabulation between the waste type and the industry type is available only for 1993. The structure of this year was extrapolated to estimate all time series, assuming that the proportion of each industry's contribution to the generation of a specific type of industrial wastes is constant for all time series.

## *DMO to Water*

Discharges of organic loads (COD) and nutrients (N, P) have been surveyed only for the drainage areas of three major closed waters (Tokyo Bay, Ise Bay, and Seto Inland Sea), where an area-wide total pollutant load control scheme has been applied. Although surveys of nutrients (N, P) were also applied to basins of major lakes and reservoirs, there is no nationwide survey. Therefore, results from these limited surveys were extrapolated, assuming that discharges per capita in nonsurveyed areas are the same as those in surveyed areas. Although population within the above-mentioned three major surveyed areas covers about 53 percent of the national total, there are considerable differences in land use, industrial structure, and discharge management between surveyed areas and nonsurveyed areas. Therefore, these results should be considered rough estimates.

### *Dissipative Use*

#### *Animal Manure*

Data on livestock excreta are available from a survey of industrial wastes, in which generation amounts as well as reuse amounts are reported. The quantities reused can be inferred as manure application, although they are reported on a fresh (wet) weight basis. On the other hand, amounts of faeces and urine from typical livestock categories are estimated both on a dry and wet weight basis by applying their emission factors per animal head. The dry to wet ratio calculated from this estimate was combined with the above statistics on reused amounts to estimate manure application in dry weight.

#### *Fertilizers and Pesticides*

Time series of used amounts of N, P, and K fertilizers were taken from the statistics of MAFF, in which figures are expressed as $P_2O_5$, N, and $K_2O$. In addition, used amounts of lime were estimated, using the consumption data of lime-containing fertilizers. Limited time series for data pesticides use in Japan are available from international sources (OECD). Interpolation was applied when necessary.

### *Domestic Hidden Flows*

All data for hidden flows were taken from our previous report (Adriaanse et al., 1997) and updated when necessary by applying the same methodology. MOC officially surveyed only excavated soils removed from construction sites (surplus soils). The total size of the excavation was estimated based on various studies in the literature including environmental impact assessment statements, land development statistics, excavation volumes announced for highway construction work contractors, among others, resulting in very rough and preliminary estimates. Soil excavated and used within the same site (cut and fill) was estimated only for new residential area development, by multiplying the factor of soil excavation works per unit area (average of several recent cases) by total area of new residential area development.

### *Contribution of Economic Sectors*

DPO was attributed to seven economic activity categories (sectors): construction and infrastructure; mining and manufacturing; energy supply; households; agriculture; transport, and other. Other generally refers to service industries. Emissions of $CO_2$ to air from fuel combustion were attributed by energy balance tables. $CO_2$ from oil consumption for international navigation and aviation was included in the transport sector. $CO_2$ from waste incineration was attributed to other. Because of the limited data availability in time series, all of $SO_2$ and $NO_x$ emissions were attributed to the energy sector. VOC emissions were included in the manufacturing sector, although they could have been attributed to other sectors, given more sophisticated data handling.

Municipal solid wastes were attributed to households, although they sometimes include wastes from small-sized service industries. Industrial wastes were attributed to the sector corresponding to the type of wastes, using sector versus waste type cross tabulation. Such a cross tabulation is available only for a single year (1993); the proportion of this year was extrapolated to all time series.

Discharges to water were originally reported as arising from three source categories:

municipal, industrial, and others. They were assumed to correspond respectively to households, industry, and agriculture in this study. Dissipative uses of manure, fertilizers, and pesticides were included in the agriculture sector. In terms of hidden flows for calculating TDO by sector, soil excavation was attributed to the construction/infrastructure sector, mining overburden was attributed to the mining and manufacturing sector, and soil erosion to the agriculture sector.

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